Remarks

Claims 1-14 are pending herein. Claims 9-13 are withdrawn as being directed to a non-elected invention. By this Amendment, claim 5 has been amended, and claim 14 has been added.

The revision to claim 5 is merely editorial. It is a grammatical correction.

New claim 14 is an independent claim that is identical to claim 1, except that claim 14 recites the specific frequency range of from 40 MHz to 150 MHz, rather than a range of 40 MHz or above. Support for the upper limit being 150 MHz can be found in the specification at, e.g., page 25, lines 12-14.

In the Office Action, claims 1 and 2 are rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Application Publication No. 2003/0080091 to Nakaune ("Nakaune") in view of U.S. Patent No. 6,593,246 to Hasegawa ("Hasegawa") and Ono, Pure and Applied Chemistry, Vol. 66, No. 6 (1994) ("Ono"); and claims 3-8 are rejected under §103(a) as being unpatentable over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of U.S. Patent No. 5,272,417 to Ohmi ("Ohmi").

In view of the amendments and remarks herein, Applicants respectfully request reconsideration and withdrawal of the rejections set forth in the Office Action.

I. Preliminary Matter

Applicants hereby affirm the telephonic election made on July 19, 2006 by Applicants' representative, Michael A. Makuch, to prosecute the invention of claims 1-8 (Group I).

II. Rejection of Claims 1 and 2

Claims 1 and 2 are rejected under §103(a) as being unpatentable over Nakaune in view of Hasegawa and Ono.

Applicants respectfully submit that claims 1 and 2 would not have been obvious over Nakaune in view of Hasegawa and Ono.

(A) Claim 1

Instant claim 1 is directed to a method of plasma-etching an organic material film formed on a substrate with an inorganic material film used as a mask. Important features of Applicants' claim 1 method include, *inter alia*:

> - the plasma-etching of an organic material film wherein an inorganic material film is used as a mask,
>
> - the use of a process gas that includes an ionization accelerating gas which (a) is ionized from a ground state or metastable state with an ionization energy of 10 eV or below and (b) has a maximum ionization cross-section of 2×10^{-16} cm^2 or above, and
>
> - a high-frequency power of a frequency of 40 MHz or above for generating plasma.

The instant specification teaches that in the conventional plasma-etching process of an organic film using an inorganic material film as a mask (described on page 1, line 20 – page 2, line 2):

> when a plasma density is increased for a higher etching rate, a self-bias voltage of the electrode is also increased. Thus, a facet formation of an inorganic material film, which is disposed adjacent to the organic material film to serve as a mask, is damaged by drawn ions, resulting in deterioration in etching selectivity of the organic material film relative to the inorganic material film. Namely, ***a high etching rate and a high etching selectivity cannot be simultaneously attained***. [emphasis added] (page 2, lines 5-13).

The use of molecular single gas or mixed gas (excluding an atomic gas such as Ar gas having a high etching action (high sputtering action)) to etch an organic material film with a high selectivity while preventing facet formation damage of the inorganic material film is disadvantageous:

> in terms of a ***considerably degraded uniformity in electron density (plasma density)***, in accordance with an electric field strength distribution. That is, a center portion of the substrate has a higher electron density, while an edge portion thereof has a lower electron density. Therefore, ***a resulting etching uniformity is unavoidably lowered.*** In particular, when a wafer has a large diameter of, e.g., 300 mm, such non-uniformity in the electron density (plasma density) is noticeably deteriorated. [emphasis added] (page 2, lines 19-26).

Applicants' claimed method is designed to achieve "both a high selectivity relative to an adjacent inorganic material film and a high uniformity in electron density or plasma density" (page 3, lines 2-4).

According to the instant specification:

> According to this method, since a frequency of a high-frequency power for generating the plasma is raised to ***40 MHz or above***, which is higher than a conventional one, ***a low self-bias voltage can be realized while maintaining a plasma density required for etching an organic material film, so that the organic material film can be etched with a high etching selectivity relative to an inorganic material film.*** Use of a process gas including an ionization accelerating gas represented by Ar, Xe, or Kr, that is ionized from a ground state or metastable state with an ionization energy of 10 eV or below and has a maximum ionization cross-section of 2 x 10^{-16} cm^2 or above, and a molecular gas, ***can significantly improve a plasma distribution, without degrading a plasma density (electron density)***. That is, ***since a gas that is ionized from a ground state or metastable state with an ionization energy of 10 eV or below and has a maximum ionization cross-section of 2 x 10^{-16} cm^2 or above can be easily ionized, addition of such gas accelerates an ionization of the process gas.*** Thus, the process gas can be sufficiently ionized near an edge portion of a substrate where an electric field strength is relatively low, whereby the process gas can be uniformly ionized as a whole. ***As a result, a uniform electron density or plasma density can be attained***. [emphasis added] (page 4, line 17 – page 5, line 9).

Thus, with the use of a high-frequency power of a frequency of 40 MHz or above to generate plasma and the use in the process gas of an ionization accelerating gas that is ionized from a ground state or metastable state with an ionization energy of 10 eV or below and has a maximum ionization cross-section of 2 x 10^{-16} cm^2 or above, Applicants' claim 1 method is able to have "both a high selectivity relative to an adjacent inorganic material film and a high uniformity in electron density or plasma density".

Regarding claim 1, the Office Action cites Nakaune for disclosing the plasma etching of an organic material by means of a parallel plate type plasma etching apparatus, wherein the organic material is plasma-etched with a high frequency power of a frequency in the range of 300 MHz to 1 GHz. The plasma-etching is carried using a process gas including an accelerating gas and a molecular gas. The accelerating gas is ionized with an ionization energy of about 0.025 ev to 1 eV and a molecular gas.

The Office Action acknowledges that Nakaune does not teach the following features:

(1) the use of an inorganic material film as a mask; and

(2) the ionization cross section of the accelerating process gas.

Hasegawa is cited for disclosing the use of an inorganic material film as a mask in the plasma etching of an organic material film formed on a substrate (col. 4, lines 65-67 and col. 9, lines 4-15). Ono is cited for disclosing an ionization cross section in the range of $2x10^{-6}$ cm^2 to about 10^{-19} cm^2 for Cl_2 process gas molecules in a plasma etching process (Figure 4, page 1331).

According to the Office Action, it would have been obvious to use an inorganic material film as a mask in the Nakaune process because "Hasegawa illustrates that by using inorganic film as a mask one can minimize damage to the low dielectric constant organic film in the step of removing the resist." In addition, the Office Action states that it would have been obvious to use the ionization cross section of molecular gas taught in Ono in Nakaune's plasma etching process because "Ono illustrates that ionization cross section of molecular gas in the etching plasma determine the etching characteristics such as etch rate, ion and electron energies and plasma densities".

Applicants respectfully submit that, for at least the reasons set forth below, claim 1 would not have been obvious over Nakaune in view of Hasegawa and Ono.

Applicants submit that it would not have been obvious to substitute the organic mask in Nakaune with the inorganic mask taught in Hasegawa. In the "Background of the Invention" section thereof, Nakaune teaches that:

> [r]ecent semiconductor elements are required to be processed with high accuracy as the structure of semiconductor elements becomes finer. Therefore, a new technology is also required to improve the

> dimensional accuracy of a masking pattern in order to process the etched material highly accurately. As a method of controlling dimensions in forming a pattern of the masking material, a technology using an anti-reflective film such as BARC (bottom anti-reflective coating) is used in order to prevent reflection of light such as ultraviolet light and to expose finely and accurately. In general, the anti-reflective film is a film made of a material which is ***the same organic group*** as a material used for the resist, and the anti-reflective film is etched by a fluorocarbon group gas or a halogen group gas mixed with oxygen, and the selective ratio of the anti-reflective film material to the masking material at processing the anti-reflective film is nearly 1. Further, edge portions of the masking pattern are apt to be cut down by sputtering at the etching, which is a trouble at processing the base etched material. [emphasis added] (paragraph [0003]).

In the "Summary of the Invention" section, Nakaune teaches that:

> [i]n order to solve the above-mentioned new problem, an ***object of the present invention*** is to provide a surface processing apparatus and a surface processing method in which the selective ratio, that is, a ratio of etching rate of ***the organic group film such as the BARC to the film made of the same group material such as the resist*** is increased, and the surface processing is performed while an initial shape of the resist is changed as small as possible. [emphasis added] (paragraph [0004]).

Thus, an object of the Nakaune invention is to increase the ratio of etching rate of one organic group film (i.e., the BARC) to another film made of the <u>same</u> organic group material (i.e., the resist). The particular process features disclosed in Nakaune are designed to achieve this object. In view of this object, Applicants respectfully submit that not only would it not have been obvious to replace the resist in Nakaune with an inorganic material such as that taught in Hasagawa, it would not have been obvious to replace the Nakaune resist with another organic material if made of a <u>different</u> organic group than that used in the BARC.

Applicants further submit that it would not have been obvious to use the ionization cross section of molecular gas taught in Ono in Nakaune's plasma etching process. Ono's teachings are directed to the plasma etching of Si, an inorganic material. On the other hand, Nakaune is

directed to the plasma etching of an organic material, specifically the plasma etching of one organic group film relative to another film made of the same organic group material. Applicants respectfully submit that one skilled in the art would not be motivated to use the ionization cross section of molecular gas taught in Ono in Nakaune's plasma etching process because the two references are directed to etching significantly different materials.

Therefore, for at least the foregoing reasons, Applicants respectfully submit that claim 1 would not have been obvious over Nakaune in view of Hasegawa and Ono.

(B) Claim 2

Claim 2 depends upon claim 1. Therefore, Applicants submit that claim 2 is patentable over Nakaune in view of Hasegawa and Ono for at least the same reason claim 1 is patentable over these references. Applicants further submit that claim 2 is patentable over Nakaune for the reasons discussed below.

Claim 2 recites in part that "the high-frequency power for generating the plasma is applied to the support electrode." Thus, the plasma is generated by applying the high-frequency power to the support electrode. An example of a support electrode is represented by reference numeral 2 in Figure 1. The instant specification teaches that:

> [b]y applying a high-frequency power (frequency of 40 MHz or above) for generating the plasma to the support electrode, an organic material film can be etched with less damage to an inorganic material film, due to a low self-bias voltage of the support electrode. (page 5, lines 16-20).

According to the Office Action, Nakaune teaches that the high frequency power for generating the plasma therein is applied to the support electrode (paragraph [0020]). However, Nakaune teaches the following:

> A disk-shaped antenna 6 for radiating a microwave of the UHF band is arranged above the gas supply plate 5, and the microwave to the antenna 6 is transmitted from an electric power supply 7 through a matching circuit 8 and a guide tube 9. (paragraph [0013]).

> A wafer mounting electrode 11 is arranged below the gas supply plate 5, and a wafer 12 is supported on the wafer mounting electrode by electrostatic attraction . . . . In order to draw the ions in the plasma into the wafer 12, a radio frequency bias is applied to the wafer mounting electrode 11 from a radio frequency electric power supply 13. (paragraph 0015).
>
> A mixed gas of H_2 and N_2 was used as the etching gas, and H_2 and N_2 were introduce at the flow rates of 100 sccm and 5 sccm, respectively. CHF_3 was added to the mixed gas as a deposition gas. The output power of the UHF microwave electric power supply was set to 1.5 kW, and the output power of the bias electric power supply 12 to the wafer was set 60 W. A resonance magnetic field of 0.016 T of UHF microwave 450 MHz was generated between the gas supply plate 5 and the wafer mounting electrode 11 (that is, the wafer 12). <u>***Then, the microwave electric power supply 7 was operated.***</u> <u>***Thereby, a strong plasma was generated***</u> in the ECR region of the magnetic field intensity of 0.016 T by the electron cyclotron resonance. [emphasis added] (paragraph [0020])

Thus, paragraph [0020] in Nakaune teaches that the plasma is generated when the <u>microwave electric power supply 7</u> is operated. As indicated in paragraph [0013], the microwave electric power supply 7 transmits microwave of the UHF band to the disk-shaped <u>antenna 6</u>, which is arranged above the gas supply plate 5 (the counter-electrode). Therefore, in Nakaune, the plasma is not generated by applying a high-frequency power to the wafer mounting electrode 11 (i.e., the support electrode). Nakaune teaches that:

> the radio frequency electric power supply 13 is operated to apply the radio frequency bias to the wafer mounting electrode 11. By doing so, ions are vertically incident to the wafer 12 from the plasma. When the bias voltage is applied to the wafer 12, etching is initiated. (paragraph [0023]).

Thus, application of high-frequency power to the wafer mounting electrode 11 in Nakaune is carried out to draw ions in the plasma into the wafer 12, not to generate the plasma. Nakaune does not teach or suggest the application of high-frequency power to the wafer mounting electrode to generate the plasma. Hasegawa and Ono do not cure this deficiency in Nakaune.

Therefore, for at least this additional reason, Applicants respectfully submit that claim 2 would not have been obvious over Nakaune in view of Hasegawa and Ono.

III. <u>Rejection of Claims 3-8</u>

Claims 3-8 are rejected under §103(a) as being unpatentable over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi.

Applicants respectfully submit that claims 3-8 would not have been obvious over Nakaune in view of Hasegawa and Ono and further in view of Ohmi.

(A) <u>Claim 3</u>

Claim 3 depends upon claim 2 and recites that a high-frequency power of a frequency of 500 kHz to 27 MHz for drawing ions is further applied to the support electrode, such that an absolute value of the self-bias voltage of the support electrode is 500 V or below.

Regarding claim 3, Nakaune is cited for disclosing the use of high frequency power in the range of 300 MHz to 1 GHz. However, the Examiner notes that Nakaune does not teach using self-bias voltage of the support electrode. Ohmi is cited for disclosing the use of self-bias of the electrode of about 400 V (col. 3, lines 3-9). According to the Office Action, it would have been obvious to "select self-bias voltage for the electrode used by Nakaune because Ohmi illustrates that applying self-bias voltage to the electrode leads [to] acceleration of ions by the potential based on the difference between the self bias voltage and the plasma potential (col. 1, lines 42-50)."

As pointed out above, claim 3 depends upon claim 2. Claim 2 recites that "the high-frequency power for generating the plasma is applied to the support electrode." Thus, the plasma is generated by applying the high-frequency power to the support electrode. As discussed above, Nakaune does not teach generating the plasma by applying a high-frequency power to the wafer mounting electrode 11 but by applying a high-frequency power to the antenna 6 (via microwave electric power supply 7). Ohmi also fails to teach generating the plasma by applying a high-frequency power to the wafer mounting electrode 11. In Ohmi, the wafer supporting electrode is the "second electrode" (see col. 4, lines 15-17 and lines 25-27). Ohmi teaches that:

> high frequency power of the first frequency (100-250 MHz) is supplied ***to the first electrode to generate a plasma*** between the electrodes, and high frequency power is of the second frequency (10-50 MHz) is supplied ***to the second electrode to control the self-bias of the second electrode***. [emphasis added] (col. 4, lines 31-36).

See also col. 9, lines 26-34, wherein Ohmi teaches that:

> After all, when the device of this embodiment is used, ***a high density plasma can be generated by high frequency power supplied to the electrode 107*** . . ., and the energy of ions irradiated on the substrate surface can be controlled to the desired value by high frequency power of f_2 supplied to the susceptor electrode 104. Thus, it is possible to perform RIE at high speed while preventing damage to the substrate 103. [emphasis added]

Therefore, regardless of whether Nakaune is modified to include Ohmi's teachings regarding the use of self-bias of the electrode, Applicants respectfully submit that the resulting modified method would not be the method set forth in instant claim 3.

Thus, Applicants respectfully submit that claim 3 would not have been obvious over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi.

(B) Claim 4

Claim 4 depends upon claim 1. Thus, Applicants submit that claim 4 is patentable over Nakaune in view of Hasegawa and Ono for at least the same reasons that claim 1 is patentable over these references, i.e., it would not have been obvious to substitute the organic mask in Nakaune with the inorganic mask taught in Hasegawa and it would not have been obvious to use the ionization cross section of molecular gas taught in Ono in Nakaune's plasma etching process. Ohmi does not cure the deficiencies in the teachings of Hasegawa and Ono. Thus, Applicants respectfully submit that claim 4 is patentable over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi.

(C) Claim 5

Claim 5 depends upon claim 3 and recites that the process gas includes argon as the ionization accelerating gas and NH_3 as the molecular gas.

According to the Office Action, Nakaune discloses the molecular gases N_2 and H_2 but fails to disclose the process gas argon as the ionization accelerating gas. Ohmi is cited for disclosing the use of argon as the ionization accelerating gas (col. 3, lines 11-12). Thus, the Office Action states that it would have been obvious to select argon as the ionization gas in the Nakaune etching process because Ohmi teaches that argon gas can be used to generate plasma with high concentration and to increase throughput (col. 3, lines 30-33).

As noted above, claim 5 depends upon claim 3 which in turn depends upon claim 2. Claim 2 recites that "the high-frequency power for generating the plasma is applied to the support electrode." As discussed in detail above, neither Nakaune nor Ohmo teaches the generating of a plasma by applying a high-frequency power to the wafer mounting electrode 11. Instead, in both Nakaune and Ohmo, the plasma is generated by applying high-frequency power to the electrode disposed opposite to the wafer support electrode. Therefore, regardless of whether Nakaune is modified in view of Ohmo to use argon, the resulting method would not be the method of instant claim 5.

Thus, for at least the foregoing reasons, Applicants respectfully submit that claim 5 would not have been obvious over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi.

(D) <u>Claim 6</u>

Claim 6 depends upon claim 3 and recites that the process gas includes argon as the ionization accelerating gas and NH_3 as the molecular gas. According to the Office Action, Nakaune discloses the use of argon as a process gas but fails to disclose the use of ammonia as the molecular gas. Hasegawa is cited for teaching the use of ammonia as the molecular gas (see col. 9, lines 51-55). According to the Office Action, it would have been obvious to select ammonia as molecular gas in the Nakaune plasma etch process because Hasegawa teaches that the molecular gas such as ammonia is useful to etch low dielectric constant organic film (see col. 9, lines 53-55).

As noted above, claim 6 depends upon claim 3 and, therefore, is patentable over Nakaune in view of Hasegawa and Ono and in further view of Ohmi for at least the same reasons claim 3 is patentable over these references. For the reasons discussed in detail in connection with the

rejection of instant claim 1, Applicants submit that it would not have been obvious to substitute the organic mask in Nakaune with the inorganic mask taught in Hasegawa. Thus, regardless of whether the molecular gas taught in Hasegawa is used in Nakaune, the result would not be the method set forth in instant claim 6.

Therefore, Applicants respectfully submit that claim 6 would not have been obvious over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi.

(E) <u>Claims 7 and 8</u>

Claims 7 and 8 each depend upon claim 3. Applicants submit that claims 7 and 8 are patentable over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi, for at least the same reasons claim 3 is patentable over these references.

(F) <u>New Claim 14</u>

New claim 14 is an independent claim that is identical to claim 1 except that claim 14 recites the specific frequency range of from 40 MHz to 150 MHz rather than a range of 40 MHz or above. Applicants respectfully submit that claim 14 is patentable over Nakaune in view of Hasegawa and Ono as applied to claims 1 and 2, in further view of Ohmi, for at least the same reasons claim 3 is patentable over these references.

IV. Conclusion

In view of the amendments and remarks herein, Applicants respectfully request that the rejections set forth in the Office Action be withdrawn and that claims 1-8 and 14 be allowed.

If any additional fees under 37 C. F. R. §§ 1.16 or 1.17 are due in connection with this filing, please charge the fees to Deposit Account No. 02-4300, Order No. 033082M257.

Respectfully submitted,
SMITH, GAMBRELL & RUSSELL, LLP

By: ______________________

Michael A. Makuch, Reg. No. 32,263
1850 M Street, N.W., Suite 800
Washington, D.C. 20036
Telephone: (202) 263-4300
Facsimile: (202) 263-4329

Dated: March 22, 2007

Enclosures: (1) Petition for Extension of Time (Three Months)
(2) Check for the Sum of $1020

MAM/MM/cvj